

## DESCRIPTION

PARTICLE BEAM IMAGE DETECTOR EMPLOYING GAS AMPLIFICATION  
ATTAINED BY PIXEL-TYPE ELECTRODES

## TECHNICAL FIELD

The present invention relates to a particle beam image detector employing gas amplification attained by pixel-type electrodes.

## BACKGROUND ART

The present inventors have previously developed, as one type of detector, an MSCG (Micro Strip Gas Chamber), which is a gas-amplification-type particle beam image detector realizing high position resolution and high incident particle tolerance and contains strip-type electrodes. Characteristic features of this detector include a very short dead time for a gas amplifier and high position resolution, and the detector has become of keen interest by virtue of its potential use as a detector for particle beams of high brightness. Presently, tests employing X-rays have confirmed that the detector is free of malfunction under a brightness of  $10^7$  counts/mm<sup>2</sup>·sec or more.

FIG. 1 is an exploded perspective view of a conventional MSGC.

The MSGC imaging device shown in FIG. 1 has an effective area of 10 cm × 10 cm. Reference numeral 1 denotes

a substrate made of polyimide thin film. Reference numeral 2 denotes an anode strip formed on substrate 1, and reference numeral 3 denotes a strip-shaped cathode electrode. Anode strips 2 and strip-shaped cathode electrodes 3 are juxtaposed alternately.

Reference numeral 4 denotes a base substrate made of ceramic, and reference 5 denotes a back-side electrode formed on the base substrate 4 and placed under the substrate 1.

Approximately distance  $D_1$  above the thus-constructed element, a drift plate 6 is provided, to thereby define a chamber for allowing passage of gas therethrough; e.g., a gas containing argon and ethane (see, for example, Japanese patent Application Laid-Open (*kokai*) No. 10-300856).

#### DISCLOSURE OF THE INVENTION

One critical problem associated with the above-described MSGC encountered during studies for putting the same into practical use is breakage of electrodes resulting from discharge between the electrodes. In the case of the existing MSGC, a voltage is applied between electrodes having a clearance of 50  $\mu\text{m}$  or less. Therefore, when a high voltage is applied in the hope of obtaining increased gas amplification factor, large current flows due to discharge between the electrodes. As a result, it frequently occurs that heat generated from discharge destroys electrode strips, or fragments of the broken electrode strips are deposited onto the surface insulating layer, resulting in malfunction

of the device due to passage of current between the electrodes.

Moreover, since signals generated in the back-side electrodes 5, which are two-dimensionally read out, have a magnitude about 20% that of the signals generated by the anodes located on the surface side, an expensive amplifier must be employed as a circuit for attaining successful read-out of such weak signals, or alternatively, amplification factor attained by gas must be further improved.

In view of the foregoing, an object of the present invention is to provide a particle beam image detector employing gas amplification attained by pixel-type electrodes, the detector having high sensitivity and electrodes of improved reliability.

In order to achieve the above object, the present invention provides the following:

[1] A particle beam image detector employing gas amplification attained by pixel-type electrodes, characterized by comprising anode strips formed on the back surface of a double-sided substrate, columnar anode electrodes which are planted in the anode strips such that their upper ends penetrate the double-sided substrate so as to be exposed to a surface thereof, and strip-shaped cathode electrodes each having an aperture such that each of the corresponding columnar anode electrodes falls therein.

[2] The particle beam image detector employing gas amplification attained by pixel-type electrodes as recited in

[1] above, wherein each of the anode strips has a width of about 200 to 400  $\mu\text{m}$ .

[3] The particle beam image detector employing gas amplification attained by pixel-type electrodes as recited in [1] above, wherein the anode strips are provided at intervals of about 400  $\mu\text{m}$ , the strip-shaped cathode electrodes each have apertures at intervals of a predetermined distance, the diameter of the aperture being about 200 to 300  $\mu\text{m}$ , and each of the columnar anode electrodes has a diameter of about 40 to 60  $\mu\text{m}$  and a height of about 50 to 150  $\mu\text{m}$ .

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded perspective view of a conventional MSGC;

FIG. 2 is a perspective view showing an essential portion of a particle beam image detector employing gas amplification attained by pixel-type electrodes according to one embodiment of the present invention;

FIG. 3 is a plan view showing one embodiment of the particle beam image detector employing gas amplification attained by pixel-type electrodes according to the present invention;

FIG. 4 is an enlarged view of the portion A indicated in FIG. 3;

FIG. 5 illustrates the operational principle of the particle beam image detector of the present invention; and

FIG. 6 shows relations of voltage applied versus gas

amplification factor attained by the particle beam image detector of the present invention.

#### BEST MODES FOR CARRYING OUT THE INVENTION

Hereafter, modes for carrying out the present invention will be described with reference to the accompanying drawings.

FIG. 2 is a perspective view showing an essential portion of a particle beam image detector employing gas amplification attained by pixel-type electrodes according to one embodiment of the present invention, FIG. 3 is a plan view thereof, and FIG. 4 is an enlarged view of the portion A indicated in FIG. 3. In FIG. 2, for the sake of easy understanding of the disposition of the anode strips, the lower section of the double-sided printed substrate is depicted to be separated from the upper section. However, it should be noted that the upper and lower sections are not separated, but constitute a unitary, double-sided substrate.

In these FIGs., reference numeral 1 denotes a particle beam image detector, 2 a pixel chamber (300 mm  $\times$  300 mm), 11 an anode strip (although width  $d_1$  is 300  $\mu$ m in the present embodiment, any width falling within the range of about 200  $\mu$ m to 400  $\mu$ m may be used), 12 a columnar anode electrode planted in the anode strip 11 (although diameter  $d_2$  is 50  $\mu$ m, any diameter falling within the range of about 40  $\mu$ m to 60  $\mu$ m may be used), 13 a double-sided substrate for a printed circuit having a thickness  $d_3$  of about 100  $\mu$ m; 14 a strip-shaped cathode electrode formed on one surface of the

substrate 13, and 21 a drift electrode.

As shown in FIG. 2, the particle beam image detector of the present invention includes a double-sided printed circuit substrate 13, strip-shaped cathode electrodes 14 on one surface of the substrate 13, and anode strips 11 on the back surface of the substrate 13. The anode strips 11 are provided at a pitch  $d_5$  of 400  $\mu\text{m}$ . The strip-shaped cathode electrodes 14 each have apertures 15 arranged at predetermined intervals. At the center of each aperture 15 is provided a pixel serving as a columnar anode electrode 12. The pixel is connected to a corresponding anode strip 11 present on the back side. The diameter  $d_6$  of the aperture 15 in the strip-shaped cathode electrode 14 is 250  $\mu\text{m}$ . However, the diameter is not limited thereto and may assume any value falling within the range of 200  $\mu\text{m}$  to 300  $\mu\text{m}$ .

As described above, in the present embodiment, the pixels serving as anodes 12 each have a diameter of 50  $\mu\text{m}$ ; however, the pixels may have a diameter of 40  $\mu\text{m}$  to 60  $\mu\text{m}$ . The anode electrodes 12 are of the columnar shape and have a height  $d_4$  of about 100  $\mu\text{m}$ , approximating the thickness of the double-sided printed substrate 13. The height of the anode electrodes is not limited to the above-mentioned specific height, and may be suitably determined within a range of 50  $\mu\text{m}$  to 150  $\mu\text{m}$ , in accordance with the thickness of the double-sided printed substrate 13.

In actual use of the detector for detecting a particle beam, the double-sided printed substrate 13 is placed in a

pixel chamber 2; i.e., in an inert-gas-based atmosphere. As shown in FIG. 2, a drift electrode 21 is provided at an appropriate position above the substrate 13 (in practice, several mm to several cm above the substrate 13) and parallel to the detector. This arrangement allows image measurement of radioactive rays similar to that attained by MSGC.

FIG. 5 illustrates the operational principle of the particle beam image detector of the present invention.

Electrons  $e^-$  produced through ionization of the gas by the incident particle beams drift under the force of a drift field toward a pixel on the substrate, the pixel serving as an anode electrode 12. In the vicinity of the columnar anode electrode 12, by virtue of the presence of a strong electric field formed by a voltage between anode and cathode (e.g., 420 V) and the pointed shape of electrode, gas avalanche amplification of electrons occurs. The  $+$  ions thus generated quickly drift toward strip-shaped cathode electrodes 14 around the ions.

In the course of the above process, electric charges are generated on the columnar anode electrodes 12 and also on the strip-shaped cathodes 14, and these electric charges are observable on the electric circuit. Therefore, observation to determine the anode or cathode strip at which this amplification phenomenon occurs provides information about the position of the incident particle beam. Reading out of signals, circuit design for obtaining two-dimensional images, etc. can be performed by use of those developed for

conventional MSGC.

Characteristic features of the present particle beam image detector are summarized as follows:

(1) Since pixels are used as anodes, strong electric fields can be easily formed, leading to an enhancement of amplification factor.

(2) Since each cathode surrounds the corresponding anode in a circular fashion, the electric field at the peripheral portion of the cathode is much weaker than that observed at the anode. As a result, flying out of electrons from the cathode is suppressed, and thus discharge does not easily occur.

(3) The electric field between the anode and cathode weakens sharply as a function of distance. Therefore, progress toward discharge may occur only in rare cases.

(4) Between the anode and cathode, an insulator is provided as a substrate. Since the width of the anode strip is larger than the diameter of the aperture of the strip-shaped cathode electrode, and the thickness of the substrate is similar to the radius of the aperture, the direction of the line of electric force is always upward at the insulator surface, eliminating any risk of generating the undesired electrostatic field caused by accumulation of positive ions generated through gas amplification.

(5) Since the present particle beam image detector essentially makes use of techniques for fabricating printed circuit boards, detectors of large area can be produced at



low cost.

(6) In the event of discharge, the detector is not fatally damaged. That is, the only damage the detector would suffer is local breakage (of some pixels).

(7) Since the detector operates under application of voltage to only two terminals; i.e., an anode electrode and a drift electrode, minimum facilities in terms of power supply and wiring are required.

FIG. 6 shows relations of voltage applied versus gas amplification factor attained by the particle beam image detector of the present invention. In FIG. 6, the x-axis represents voltage (V) applied between the cathode and the anode, the y-axis represents gas amplification factor (logarithmic scale), line "a" represents a characteristic curve according to the present invention, and line "b" represents that obtained from a conventional detector.

As is apparent from FIG. 6, an amplification factor of 10,000 or thereabouts can be attained by the present invention. Also, when the detector of the present invention was operated for two days continuously at an amplification factor of about 1,000, not even a single occurrence of discharge arose. At higher amplification factors, discharge was observed, but rarely, with no subsequent operational problems.

Although the present invention has been described above with reference to specific embodiments, the invention is not limited to those embodiments. Numerous modifications and

variations of the present invention are possible in light of the spirit of the present invention, and they are not excluded from the scope of the present invention.

As described above in detail, the present invention provides the following advantages and effects among others.

(A) The detector of the invention has the same advantages as those of MSGC. That is, the inventive detector attains a large gain and has improved reliability of electrodes.

(B) Since pixels are used as anodes, strong electric fields can be easily formed, leading to an enhancement of amplification factor.

(C) Since each cathode surrounds the corresponding anode in a circular fashion, the electric field at the peripheral portion of the cathode is much weaker than that observed at the anode. As a result, flying out of electrons from the cathode is suppressed, and thus discharge does not easily occur.

(D) The electric field between the anode and cathode weakens sharply as a function of distance. Therefore, progress toward discharge may occur only in rare cases.

(E) Between the anode and cathode, an insulator is provided as a substrate. Since the width of the anode strip is larger than the diameter of the aperture of the cathode electrode, and the thickness of the substrate is similar to the radius of the aperture, the direction of the line of electric force is always upward at the insulator surface,

eliminating any risk of generating the undesired, cancelling electrostatic field caused by accumulation of positive ions generated through gas amplification.

(F) Since the present particle beam image detector essentially makes use of techniques for fabricating printed circuit boards, detectors of large area can be produced at low cost.

(G) In the event of discharge, the detector is not fatally damaged. That is, the only damage the detector would suffer is local breakage (of some pixels).

(H) Since the detector operates under application of voltage to only two terminals; i.e., an anode electrode and a drift electrode, minimum facilities in terms of power supply and wiring are required.

#### INDUSTRIAL APPLICABILITY

The particle beam image detector according to the present invention employing gas amplification attained by pixel-type electrodes is suitable for technical fields involving detection of radioactive rays; i.e., monitoring of radioactive rays, X-ray image analysis, medical use X-ray imaging, and new techniques of gamma-ray imaging.